

## **PROJECT MANAGEMENT IN GEOTECHNICAL SERVICES**

### **INTRODUCTION**

Geotechnical Services (GS) is dedicated to delivering quality projects within budget and on schedule. In pursuing this goal, GS closely collaborates with District project managers and DES – Project, Program and Resources Management (DES – PPRM). Besides possession of highest technical knowledge and merits in the geotechnical engineering field, GS professionals are required to have a general knowledge of the key concepts of project management and its standards.

There is extensive literature in the field of project management available from Caltrans and external sources. Division of Project Management has published a [Project Management Handbook](#) as well as a wealth of other directives, policies and handbooks related to this field. DES-PPRM has also published various guidelines to further assist DES employees with project management issues. The purpose of this chapter is to provide an overview of the basic concepts and processes of project management as they apply to GS practice.

In preparing this chapter, “A Guide to the Project Management Body of Knowledge (PMBOK Guide), Fourth Edition” has been used as the formwork and major reference. Published by the Project Management Institute, PMBOK is an internationally recognized standard for the project management profession. PMBOK has defined nine knowledge areas in project management. However, only six knowledge areas with direct applicability to GS practices will be discussed in this chapter. These are scope management, time management, cost management, quality management, communication management and risk management.

In reviewing this chapter, it is strongly recommended that the reader also review other documents that have been referred to using the provided links. All the references are considered essential in developing a basic understanding of the topics.

### **PROJECT SCOPE MANAGEMENT**

Project scope management consists of activities and processes that define and control the work required to produce the desired deliverables. Geotechnical Services conducts investigations and studies and provides services to a variety of clients during all phases of project development. The scope of products and services furnished by GS is a function of the overall project objectives, project phase and client needs. It is of utmost importance for the geoprofessional to have a clear understanding of client expectations as

well as project constraints and to establish a well defined scope through the required processes before start of work.

This section provides an overview of scope management in GS. This includes scope definition and verification and discussion of GS deliverables and milestones in Caltrans Work Standard Guide. Furthermore, scope change control methods and required documentation will be discussed.

## **Scope Definition and Verification**

GS serves clients throughout a project life cycle from the initiation phase to construction and post construction (maintenance support). With a wide range of clients within Districts and DES, the scope of GS deliverables varies significantly depending on the project phase. Although GS products can be considered fairly standard, each project is unique and has its own features, requirements and constraints. Moreover, one should distinguish between the product scope as the sum of all required deliverables and the project scope which is all the work to be performed to produce the deliverables and achieve the project goals.

As part of the Service Agreement process for capital projects, DES-PPRM usually arranges Service Agreement Meetings with District clients to discuss the scope and schedule of DES deliverables and achieve a common understanding of the required services. The outcome of these discussions is summarized in the Statement of Assumptions and Deliverables of the Service Agreement and is outlined in detail for different DES functional units including GS. Although this process is extremely useful and provides solid grounds for a scope agreement at the project level for capital outlay program, it may still not be sufficient for geoprofessionals to completely identify the scope of their work.

GS work usually commences upon receipt of a request from one of the clients such as District Design, Structure Design, Maintenance, Planning, Legal, etc. At this stage, it is imperative for both GS and the client to communicate effectively, and thoroughly discuss the client's expectations. It is advisable that the parties at this time agree upon a scope statement. The agreement maybe formal and in writing or informal through verbal communication. In the latter case, the agreement details should be documented and filed. Once the required deliverables have been identified, the geoprofessional can start developing a project scope within GS and plan the activities. This effort involves identifying and planning the geotechnical work elements needed to produce the deliverables.

It must be noted that while drafting a product scope requires mutual understanding and agreement between the client and GS, establishing a geotechnical project scope is done at

the sole discretion of the geoprofessional. Considering the deliverable as the product, the geoprofessional must use expert judgment to outline all necessary activities and propose a project scope, i.e., a geotechnical investigation/study plan. Elements of this plan whether it entails subsurface exploration, in situ testing, soil sampling, lab testing or a combination of all must be discussed with and agreed upon by the first line supervisor.

Upon completion of work and delivering the products, GS should seek the acceptance of the client. The process of obtaining the formal acceptance of a client is usually referred to as scope verification. In performing scope verification, it is common for geoprofessionals to initially provide the client with draft deliverables and finalize them once they are verified to have successfully met the client requirements. Scope verification may lead to change requests that will be further discussed in this section.

## **Work Breakdown Structure and Workplan Standard Guide**

A Work Breakdown Structure (WBS) is a deliverable-oriented grouping of project work elements in a hierarchical manner that defines the project scope. Descending order of WBS elements identifies additional details of deliverables with the actual work packages at the lowest WBS levels. Since 1994, Caltrans has been using a WBS template for its capital outlay support program. This template includes all the work elements that any capital project may entail, and is used as a guide to establish project specific WBS for any particular project. The project specific WBS is used to build the project workplan.

The Caltrans WBS template has undergone several revisions and updates. The latest version of WBS could be obtained from [“Workplan Standard Guide for Delivery of Capital Projects, Release 10.2, June 2012”](#). A detailed description of Caltrans WBS is beyond the scope of this document. It must be noted, however, that GS staff should be familiar with Caltrans WBS and its corresponding coding structure as it is the basis for GS project activities, resource estimating and charging practices.

In summary, WBS levels 0 through 4 represent Department, District, Program, Project and Component, respectively. Major project deliverables are identified at WBS level 5. Geotechnical Services contributes to several WBS level 5 elements; however, is not the designated “Task Manager” for any of them. WBS levels 6, 7 and 8 identify lower level deliverables. GS is in responsible charge for managing several level 6 through 8 WBS elements. Table 1 presents a list of WBS level 6 through 8 elements for which GS is either lead task manager or a contributing DES subdivision.

**Table 1. GS WBS Levels 6, 7 and 8**

<b>Project Phase</b>	<b>WBS</b>	<b>Description</b>	<b>GS is Lead Task Manager</b>	<b>GS Contributes</b>
<b>K</b>	100.05	Project Management - PID Component		x
	150.05.10	Geological Hazards Review	x	
	150.10.10	Value Analysis		x
	150.15.20	District Preliminary Geotechnical Report (DPGR)	x	
	150.15.30	Structures Advance Planning Study (APS)*		x
	150.25.20	PID Circulation, Review & Approval		x
	150.25.25	Storm Water Data Report		x
<b>0</b>	100.10	Project Management - PA&ED Component		x
	160.05.10	Geotechnical Information Review		x
	160.10.20	Value Analysis		x
	160.10.80	Updated Geotechnical Information	x	
	160.10.85	Structures Advance Planning Study (APS)*		x
	160.15.25	Draft Project Report Circulation, Review, & Approval		x
	180.05.15	Updated Storm Water Data Report		x
	180.10.05.05	Draft Final Environmental Document Review		x
<b>1</b>	100.15	Project Management - PS&E Component		x
	185.15.20	Value Analysis		x
	185.20.15	Preliminary Geotechnical Design Report (PGDR)	x	
	230.05.30	Construction Details		x
	230.05.70.10	Products Required to Ready Site for Subsurface Exploration		x
	230.05.70.15	Geotechnical Design Report (GDR)	x	
	230.35.05	Roadway Specifications		x
	230.60.05	Updated Storm Water Data Report		x
	240.65	Preliminary Foundation Report (PFR)	x	
	240.70	Products Required to Ready Site for Subsurface Exploration	x	
	240.80	Foundation Report (FR)	x	
	250.50	Project Review (Final Structures PS&E Package)		x
	255.05	Circulated & Reviewed Draft District PS&E Package		x
	255.10.25	Updated Technical Reports		x
	255.25	Geotechnical Information Handout		x

<b>Project Phase</b>	<b>WBS</b>	<b>Description</b>	<b>GS is Lead Task Manager</b>	<b>GS Contributes</b>
<b>3</b>	100.20	Project Management - Construction Component		x
	270.20.30	Contractors' Trenching and Shoring Submittals Review		x
	270.20.40	Cost Reduction Incentive Proposals (CRIPS) Review		x
	270.20.50	Technical Support		x
	270.25.15	Pre-Construction Meeting		x
	270.30.10	Inspection of Contractors' Work for Compliance		x
	275.10	Office Administration for Structures		x
	275.20	Field Administration Work for Structures		x
	275.30	Contract Change Order Inspection for Structure Work		x
	275.40	Safety Tasks for Structures Work		x
	285.10.15	Other Functional Support		x
	290.05	Analysis of Notices of Potential Claims		x
	290.10	Supporting Documentation and Responses to Notices of Potential Claims		x
	290.15	Reviewed and Approved Claim Report		x
	290.20	District Claim Meeting or Board of Review		x
	290.25	Arbitration Hearing		x
	290.35	Technical Support		x

\* Includes preparation of SPGR

## Scope Change Control

The initial agreement between GS and clients on the scope of services and products establishes the scope baseline. Scope baseline rarely remains unchanged during the project life cycle. Numerous internal and external factors may result in a need for change in the scope baseline. Change in stakeholder needs, right of way requirements, geometrics, environmental constraints and resource and regulatory agency regulations are among several factors that could trigger a change in the scope baseline. Since change is virtually intrinsic to any project, it must be continuously monitored and its impacts on project objectives be evaluated and controlled if necessary.

In order to facilitate documentation and communication of change, DES has developed the Change Communication Document (CCD). This document serves as a consistent means of communicating project changes with the PM, affected DES functional units including GS and other project stakeholders. In essence, a CCD must be filed once DES recognizes a change in scope, schedule or cost baseline at the highest WBS level at which DES is the lead task manager and reports directly to District. A CCD generally

documents the change, its trigger(s) and its impact on scope, schedule and cost. It further outlines the associated risks, resolution alternatives and the agreed upon approach. The CCD will assist the PM with preparing a Project Change Request (PCR) if one is warranted.

As previously stated, a change in the scope baseline is not the only reason for filing CCD and this document may also be required if there is a change to DES delivery schedule as well as a change in capital and support costs. Further discussion regarding filing CCD due to schedule and cost changes will be presented under Project Time Management and Project Cost Management sections.

CCD guidelines, forms and examples may be obtained from DES-PPRM web pages at: [http://onramp.dot.ca.gov/hq/esc/pprm/Project\\_Management\\_Change\\_Communication\\_Document.html](http://onramp.dot.ca.gov/hq/esc/pprm/Project_Management_Change_Communication_Document.html)

## **PROJECT TIME MANAGEMENT**

One of the important responsibilities of a geoprofessional is to develop a schedule for delivery of geotechnical products and services that falls within the Structures delivery schedule (in case of structural work) and overall project schedule. In general, there are several processes that result in developing a project schedule. This task usually starts with identifying the required activities for producing deliverables and their dependencies. In the next step, the duration of activities and the required resources for performing them must be estimated. A geotechnical project schedule may then be developed based on analysis of this information. In reality, all these processes are closely connected in generating a geotechnical project schedule and could be viewed as a single process.

The main objective of this section is to provide an overview of this process. Activity definition and sequencing will be briefly discussed and activity duration estimating will be addressed along with schedule development. A discussion of the impact of change requests on schedule baseline will also be presented. The topic of activity resource estimating will be addressed under Cost Management later in this Chapter.

### **Activity Definition and Sequencing**

As previously stated under Scope Management, upon a mutual agreement on the product scope, the geoprofessional can proceed with establishing a geotechnical project scope baseline. Considering the project deliverables, assumptions and constraints, he/she should exercise expert judgment and use proper techniques to define and verify the specific activities required and their sequence.

There is a wide range of activities required for geotechnical projects. Searching in report and as-built archives, performing initial field reconnaissance, preparing geotechnical investigation plan, obtaining right of entry and regulatory agency permits, acquiring environmental and utility clearances, scheduling drilling and lab testing, engineering analysis and design and developing reports are examples of activities common to most geotechnical projects. It is recommended that as the first line of action, the geoprofessional establish a comprehensive list of activities that are deemed necessary and identify the milestones. Utilizing the list of activities in previous and similar projects as a template is usually helpful in performing this task.

Once the list of activities is developed, the logical relationship between the activities must be examined. During this process, the predecessor-successor dependencies are determined and the sequence of activities is identified. It is important to clearly identify the types of logical relationships and dependencies as the outcome will directly impact the duration and schedule.

### **Schedule Development**

A major challenge in developing an internal GS project schedule is estimating the duration of activities. This is particularly the case for activities that are mostly performed outside GS, e.g., activities required to ready site for subsurface exploration. Obtaining drilling permits from regulatory and resource agencies or acquiring right of entry permits are examples of activities that are generally conducted outside GS. Consequently, expectation of a reliable estimate of duration of these activities may not be realistic. However, a geoprofessional can estimate the duration of GS activities with relative confidence if the available resources are clearly identified.

In performing this task, the geoprofessional can rely on informed judgment and historical information. In larger and more complex projects where overall project schedule could be highly sensitive to timeliness of GS deliverables, the three-point estimate method (also known as PERT analysis) maybe useful. In this method, three estimates of the duration of each activity are computed based on pessimistic (P), optimistic (O) and most likely (M) scenarios. The weighted average of the three estimates will then be calculated according to the following equation and used as the final estimate of duration (D):

$$D = (P + 4M + O)/6$$

The main purpose of developing a geotechnical schedule is to ensure that the overall project milestones will be met. Therefore, there is usually no need to apply sophisticated techniques such as Critical Path Method or Schedule Network Analysis to establish a GS internal schedule. It is important for a geoprofessional, however, to be familiar with some of these methods and utilize them when necessary to improve efficiency.

Considering the limited available resources for activities such as drilling, in situ testing and instrumentation, basic knowledge of schedule compression techniques such as crashing and fast tracking may be necessary for optimizing a geotechnical schedule. While the former involves analyzing schedule and cost tradeoff, the latter focuses on performing activities in parallel in lieu of sequencing to achieve the maximum compression. With careful application of these techniques, geotechnical managers may navigate through options for overtime approval and A&E contract to maintain a delivery schedule in a cost effective manner.

The geotechnical project schedule will include all identified activities with planned start and finish dates. A graphic presentation of schedule such as a bar chart can also be used and may be more appropriate for complex projects.

### **Schedule Control**

GS usually requires a target delivery deadline along with any request from clients. The deadline is used in developing a geotechnical schedule as described before. The resulting initial schedule is considered the schedule baseline. A change in schedule baseline could occur due to a variety of reasons. Scope change, change in resource availability, delay in obtaining required permits or clearances and policy changes are among factors that may result in a change in schedule baseline.

The purpose of schedule control process is to monitor the project status from a schedule standpoint and to manage potential changes to the schedule baseline. As discussed previously, in order to document, manage and communicate major project changes, DES has developed the Change Communication Document (CCD). A CCD must be filed if considerable changes to geotechnical schedule baseline may impact the Structure PS&E schedule and/or the overall project schedule. Minor changes, however, may be discussed with the client and a mutually agreeable geotechnical delivery schedule can be negotiated accordingly.

## **PROJECT COST MANAGEMENT**

In recent years and with the passage of SB 45, local governments and agencies have gained increasing control over transportation projects on State highways. Applying stricter budgetary control measures by local agencies has created serious challenges for Caltrans in Capital Outlay Support program. In order to maintain steady workload and staffing in this program, Caltrans has to stay competitive with other agencies and the private sector. This fact highlights the importance of estimating reasonable support costs



to win the bid for delivering projects as well as monitoring expenditures to avoid budget overruns once the projects are delivered in-house.

Geotechnical Services is committed to delivery of projects within the approved budget. With the exception of providing rough or order of magnitude estimate during the initiation phase of capital projects or to support Maintenance in developing Damage Assessment Forms, GS staff is not directly involved in estimating capital costs. It must be noted, however, that providing economical designs and reliable engineering reports by geoprofessionals will result in projects that are most cost effective and can positively impact the project budget.

In this section, the process of estimating support costs (resources) in GS will be discussed. An overview of general methods of resource estimating methods will be presented and the DES-PPRM practice and GS bottom-up estimating approach will be explained. Proper charging practices and their impact on budget control is another topic of interest that will be addressed. Application of effective cost control measures and Earned Value Management techniques will also be discussed.

## **Resource Estimating**

Resource estimating is the process of evaluating the staff effort required for delivery of a project. This approximation can be performed either in terms of support cost dollars or person-hours. However, since workplans in Caltrans are developed based on the estimated hours, the latter will be discussed in this section.

Uncertainties involved in the estimating process makes it a challenging task. Care must be exercised in preparing estimates so that they are as reliable and realistic as possible considering all the facts, assumptions and constraints. The importance of reasonable resource estimates is highlighted by the fact that they are the major means for competing with other service providers. Furthermore, evaluation of staffing needs of any Division in the capital outlay program is linked to its resource allocations.

DES-PPRM has the overall responsibility of negotiating resources with Districts and obtaining allocations for DES. This task is performed through the Service Agreement process during which, the District and DES agree upon delivering a project as a certain support cost and according to the project delivery schedule prepared by District. Project Liaison Engineers (PLE's) assigned to different Districts are tasked with conducting and monitoring the Service Agreement process. Estimating the required resources for various subdivisions of DES is a major part of this process. In performing this task, PLE's heavily rely on the input provided by Task Mangers of different DES functional units. With a close knowledge of the scope, Task Managers are the most qualified to evaluate the resource needs for their respective units and provide the estimates to PLE's.

Several department policies and guidelines such as “[Deputy Directive 93 – Task Management](#)” and “DES/PPRM Directive 08-01, Task Management for Project Delivery” have explained the roles and responsibilities of Task Managers during the project delivery process. Among several other responsibilities, DD-93 specifies that Task Managers (TM’s) are responsible for reasonableness and acceptability of resource estimates for their portion of project and have to commit to it. DES Directive 08-01 further expands on the accountability concepts and holds TM’s responsible for resource estimates that are incorporated in the DES Service Agreement. In summary, lead TM’s in GS are ultimately responsible for providing reasonable resource estimates for inclusion in Service Agreements.

Among several cost or resource estimating methods that are vastly used in the industry, the following three are more common in Caltrans workplans:

### 1 – Analogous or Top-Down Estimating

In this method, one can estimate support costs of a current project using the actual expenditures on a previous similar project. This method can be used in early phases of a project where sufficient scope information is not yet available. Project Managers usually use this estimating method in the initiation phase to develop a preliminary workplan for programming purposes. It is imperative that the numbers derived from this method be revisited in the later phases and be replaced by more accurate estimates based on the actual scope.

### 2 – Parametric Estimating

This technique relies on historical information to find a correlation between one or several of project parameters such as capital cost and the required support costs. Work Estimating Norms (WEN’s) developed by DES-PPRM have mostly used this method. PLE’s have widely used these WEN’s in preparing first draft resource estimates for inclusion in Service Agreement and circulation among DES functional units.

The DES WEN used for GS resources was originally developed for structure foundation projects, six broad categories of roadway projects and oversight of special funded projects. This WEN has been revised and updated in recent years with GS assistance to provide more reasonable estimates for the initial runs. The WEN currently links the GS required resources for special design structures to estimated resources for Structure Design (SD). A fraction of the estimated SD hours is further broken down among all involved GS cost centers according to certain formulas and under various WBS elements. The method used in this WEN for roadway projects has a top-down nature and is merely capable of generating rough estimates.

### 3 – Bottom-Up Estimating

This detailed method produces estimates at the lowest possible work package levels considering specifics of the scope. The individual estimates are then combined and rolled up to higher levels to subsequently generate the overall support cost at the project level. This technique is time consuming but generally yields the most accurate estimates compared to other methods.

The first version of a uniform GS WEN based on bottom-up estimating techniques was developed in 2005. This norm that is the most comprehensive GS estimating tool, utilizes detailed geotechnical scope information to estimate the required resources for GS cost centers. User usually needs information such as total length of earth retaining systems and soundwalls, extent of cut and fill slopes and landslides and number of bridge supports and sign foundation as the initial data. This information along with several assumptions will be used to initially evaluate the effort needed for subsurface explorations. The norm can further estimate the required resources for conducting in-situ and laboratory testing as well as engineering analysis and design of the project. The tool is capable of developing a breakdown of estimated resources for each GS function and under various WBS elements. The summary output can be provided to PLE's for inclusion in workplans.

GS WEN has undergone several revisions and updates to conform to the latest Workplan Standard Guide (WSG). The latest version of the tool can be downloaded from the GS web pages at: <http://www.dot.ca.gov/hq/esc/geotech/>

Similar to all other bottom-up estimating tools, GS WEN requires a number of assumptions such as production rate and week hours for drilling and CPT operations, etc. A recent list of such assumptions are presented in Table 2 below:

**Table 2. Rate Assumption Reference for GS WEN**

GS Office	Task and WBS Element(s)	Unit	Hours per Unit	Remarks
<b>Drilling Services</b>	Drilling (230-240)	Drill-Week	220	Based on a drill crew of 3 foundation drillers plus supervisors and office support. Typical production rate is 200' total depth of drilled hole per drill-week.
<b>Geotechnical Support</b>	CPT (230-240)	Work-Week	100	Based on a CPT crew of 2 technicians plus half engineer time per work-week. Typical production rate is 8 soundings up to 50' deep per day and 3 working days per week.
	Instrumentation (230-270)	Site	280	Includes installation of 3 SI's and 2 piezometers per site and biweekly monitoring for 5 months by an engineer and a technician.
	GGL for CIDH Piles (275)	CIDH Pile	30	Average number for CIDH piles between 24" and 96" in diameter and 100' long. Testing additional piles in the same visit is done at a 75% reduction factor.
	PDA for Driven Piles (275)	Pile	180	One single driven pile with 2 to 4 instrument packages. Requires field acceptance criteria including GRLWEAP analysis.
	Static Pile Load Test (275)	Pile	1200	Perform a static axial pile load test in both tension and compression.
	Geophysics, Surface (230-240)	Profile	90	Average number for a seismic refraction profile with no explosion assuming level ground and simple stratigraphy.
	Geophysics, Borehole (230-240)	Borehole	50	Average number for basic logging.
	Lab Tests (230-240)	Borehole	250	Per 6 boreholes 80'-100' deep, mostly sandy soils. MA, PI and shear strength tests.
<b>Drafting Services</b>	Drafting LOTB's (230-240)	LOTB	12	Average number per log for a 100' deep hole.

## Charging Practices

All GS employees are responsible to accurately report labor expenditures for the work they perform. The importance of accurate charging practices is that they result in enhanced financial control of projects and will lead to more effective project management in general. Moreover, with increased control of local agencies and governments over transportation budget and federal funding of a variety of projects, it is imperative to charge and bill project expenditures properly. With tighter budget constraints, there is a growing trend of applying scrutiny over direct and indirect charges by Project Managers.

[“Deputy Directive 41 – Caltrans Charging Practices”](#) has outlined the proper charging practices and has explained the roles and responsibilities of all managers (executives,

resource managers, task managers, etc.) and supervisors as well as employees in this regard. In addition to [DD-41](#), there are other directives and guidelines specific to DES employees. DES-PPRM has issued “Charging Practice Guidelines” and has periodically updated the document to further assist DES staff with this task. The latest guidelines can be viewed at:

[http://onramp.dot.ca.gov/hq/esc/pprm/Project\\_Management\\_Charging\\_Practices.html](http://onramp.dot.ca.gov/hq/esc/pprm/Project_Management_Charging_Practices.html)

GS has more specific charging instructions gathered in a reference sheet for capital outlay support projects and training as well as capital corporate overhead activities; research overhead activities, local assistance, traffic operations and maintenance. The reference sheet is updated periodically and can be obtained from the aforementioned website.

## **Cost Control**

The initial allocations placed in the project workplan for each functional unit usually constitutes the support cost baseline. Any change to the cost baseline must be generally monitored and managed. Cost control is the process of monitoring the status of project budget and managing changes to the baseline. Two major elements of the cost control process are monitoring the expenditures against the work performed and ensuring that no budget overrun will occur, i.e., expenditures will not exceed the allocations.

Earned Value Management (EVM) is a project management methodology that if applied properly, can effectively gauge performance through schedule, cost and progress integration. A number of Districts have been utilizing this methodology in recent years and have devised online tools for EVM implementation. These tools assist Task Managers in monitoring the status of their projects and taking corrective actions should the cost or schedule is not on target. A driving force behind this move has been the strong demand by local agencies that provide funding for State transportation projects. EVM tools are capable of generating progress reports that are generally required by these agencies. In July 2012, [Project Delivery Directive PD-08](#), officially introduced EVM as one of the tools that Caltrans utilizes to manage cost and schedule in capital outlay projects. The following key elements are the basis of the EVM methodology:

Planned Value (PV) is the budget authorized for completion of an activity or WBS element. It is also referred to as the Budgeted Cost of Work Scheduled (BCWS). The term Budget at Completion (BAC) is usually used to refer to total planned value of a project.

Earned Value (EV) is the value of the work performed for an activity or WBS element. EV is a measure of completion percentage for that activity or WBS component. It is also referred to as the Budgeted Cost of Work Performed (BCWP).

Actual Cost (AC) is the total actual cost incurred in completion of an activity or WBS element. Another term for AC is the Actual Cost of Work Performed (ACWP).

With these key elements, the actual progress of work in terms of cost and schedule can be measured using the following indexes:

Schedule Variance (SV) is defined as the difference between the Earned Value and Planned Value ( $SV = EV - PV$ ). An SV greater than zero indicates the work is ahead of schedule while a negative SV is an indication of being behind schedule.

Cost Variance (CV) is the difference between Earned Value and Actual Cost ( $CV = EV - AC$ ). A positive CV indicates that work has been performed under budget while a negative CV implies a budget overrun.

Schedule Performance Index (SPI) is the ratio of Earned Value to Planned Value ( $SPI = EV/PV$ ). For a project to be on or ahead of schedule, SPI has to be equal or greater than one.

Cost Performance Index (CPI) is the ratio of Earned Value to Actual Cost ( $CPI = EV/AC$ ). CPI values equal or greater than one imply the work has been performed at or under the budget.

In general, the financial health and/or timeliness of a project or any component of it can be measured by one of the aforementioned indexes.

Project Resource and Schedule Management (PRSM) to be discussed later in this chapter, incorporates the EVM as a reliable technique to report current project status. In order for EVM to be effective, GS Task Managers must periodically provide status updates for their tasks. The frequency of updates varies based the WBS component level. Entering accurate and timely task progress and task completion data into PRSM ensures reliable overall status results.

DES-PPRM has published the [Earned Value Management Guidance](#) to assist the DES staff with using PRSM and improving the progress reporting associated with it. Among other useful information, this document establishes earning rules for WBS elements and provides standardized task percentage complete definitions. Standard percent complete for WBS level 5 and 6 managed by various DES subdivisions are presented in the document tables.

Currently, GS is level 6 Task Manager for WBS 240.65, 240.70 and 240.80. The following table summarizes the percent complete information from the above cited document for level 6 WBS elements managed by GS:

**Table 3. Summary of Percent Complete Data for GS Tasks**

<b>WBS Level 6</b>	<b>Task Manager</b>	<b>Description of Work</b>	<b>% Complete</b>
<b>240.65 Preliminary Foundation Report (PFR)</b>	GS	Collected As-Built Foundation Data and Other Existing Project Information	50
	GS	Completed PFR	100
<b>240.70 Products Required to Ready Site for Subsurface Exploration</b>	GS	Developed Subsurface Exploration Plan, Obtain Permits and Physical Accessibility	50
	GS	Site Ready for Subsurface Exploration	100
<b>240.80 Foundation Report (FR)</b>	GS	Completed Subsurface Exploration	50
	GS	Completed Field and Lab Testing	65
	GS	Completed FR	95
	GS	Completed Log of Test Borings(LOTB)	100

## PROJECT QUALITY MANAGEMENT

Quality management in general is a group of processes and activities that first define the quality metrics and requirements and then establish policies to comply with them. Quality management is critical to success of any project and its products. Successful implementation of quality management in an organization requires a clear understanding of the concepts, processes involved and roles and responsibilities of the project team members and functional managers.

Quality has its own costs and benefits. Low quality products result in customer dissatisfaction and potential rework. On the contrary, establishing extremely high and unreasonable quality standards may incur high costs and create work backlogs and is not generally sustainable. A systemic commitment to quality improvement and practice of quality management is essential to any organization.

In recognition of need for continuous improvement, Geotechnical Services issued its Quality Management Program in May 2012. This program, herein referred to as [GSQMP](#), is augmented with several specific quality management plans for GS design offices, drilling services and geotechnical support branches. For a comprehensive discussion of GS quality management policies and implementation plan, the reader is referred to [GSQMP](#).

## **PROJECT COMMUNICATION MANAGEMENT**

Effective communication is the key to successful project delivery. The purpose of communication in an organization is to get the right information to the right people in a timely manner. Communication management includes several processes that are required for generation and distribution of information to project stakeholders. These processes include planning suitable communication methods, distributing information, managing stakeholder requirements and performance reporting.

Geotechnical Services utilizes all available means of communication and adheres to the guidelines and requirements of DES Business Practice 11-01, [Agreement on Timely Response](#).

### **Information Distribution**

Communication between GS and project stakeholders including clients may take place in a variety of formats depending on specific project needs. Information may be distributed verbally or in writing, in a formal or informal manner and using the appropriate choice of media (traditional document distribution or various electronic communication options).

With the exception of emergencies, GS usually requires written requests from clients to commence studies and investigations. Upon receiving a project assignment, GS staff are required to communicate with the client and acknowledge the receipt of their request. During the initial communication, issues such as supporting project information and documents, schedule, delivery deadline and logistics are usually discussed. Interaction and communication with clients continues throughout the process of conducting geotechnical studies.

GS primarily relies on developing technical reports to distribute the outcome of its studies among clients and stakeholders. The “[Communications and Reporting](#)” chapter of this manual provides all the information relevant to generating reports in GS. This chapter includes a comprehensive list and description of GS reports and products as well as useful information such as guidelines for report formats and distribution lists.



Geoprosessionals are required to actively participate in PDT meetings, discuss project issues and exchange information with other stakeholders. Furthermore, GS staff utilizes formal or informal presentations to either share project specific information or raise general awareness on types of services that GS provides.

## **Performance Reporting**

This process involves collecting and providing information regarding project performance measures and project status. Comparing baseline and actual data on scope, cost and schedule is a major objective of performance reporting. These reports may further serve as basis for project forecasts.

GS participates in District and DES status review meetings. The major goal of these meetings is to discuss the latest status of projects, review the progress of functional units, exchange information and identify major issues and hurdles that could jeopardize the delivery.

GS maintains an electronic project tracking system to record and report project status information. The project tracking records include basic project information as well as the latest status of project activities and products. GS further contributes to eSSOP, the major electronic database for status of structures project. This comprehensive database uses data from various DES subdivisions and incorporates scope and schedule information with task management principles to provide the latest status of Structure Design projects.

## **PROJECT RISK MANAGEMENT**

Risk is identified as an uncertain event or condition that upon occurrence may affect the project objectives (cost, schedule, scope, quality) in a positive or negative manner. While the former is referred to as an opportunity, the latter which is called a threat is usually the main focus of attention and subject of analysis. Geotechnical engineering involves evaluating the physical and mechanical properties of soil and analyzing its behavior under various environmental and loading conditions. This evaluation is usually based on limited subsurface investigation, sampling and in situ and laboratory testing. In other words, geotechnical engineering embarks on the tremendous task of developing design and remedial measures for large scale roadway and structure project based on small scale subsurface soil exploration and evaluation. Consequently, “risk” is intrinsic to the geotechnical engineering practice and risk management must be an integral part of any geotechnical study.

Risk Management is one of the knowledge areas of project management and can be described as the practice of identifying, prioritizing, quantifying, responding to and monitoring risks from inception to completion of a project. [Project Delivery Directive PD-09](#) dated July 1, 2012, has mandated the application of risk management to all capital and major maintenance project and has further directed functional units to incorporate project risk management requirements into their guidelines and manuals by July 1, 2013.

Literature on risk management concepts and applications is vast. Caltrans has issued the [“Project Risk Management Handbook: A Scalable Approach”](#) dated June 2012, to further assist with implementation of risk management within the Department. The purpose of this section is to present a focused view of risk management from a geotechnical standpoint and to comply with the requirements of [PD-09](#). It is further intended to assist geoprofessionals to gain a better understanding of the principles of risk management and its applications to their projects. It is the responsibility of the geoprofessionals to ensure that risk management implementation within Geotechnical Services fits into the overall project risk management activities.

## **Project Risk Management Planning and Organization**

Caltrans has adopted a three-tiered scalable approach to implementation of risk management where the type and level of risk management activities is a function of the project cost and its level of complexity. According to this approach, major projects are divided into three groups based on their total (capital and support) costs with increasing minimum risk management requirements defined as levels 1, 2 and 3. Comprehensive description of this system can be found in the [“Project Risk Management Handbook: A Scalable Approach”](#). Involvement of Geotechnical Services at each level will be further discussed in this section.

A Project Risk Management Team (PRMT) which is normally comprised of a number of Project Development Team (PDT) members is tasked with conducting risk management activities under the direction of the Project Risk Manager. Geoprofessionals are an integral part of any PRMT for projects with GS involvement and must actively participate in all team endeavors. As a PRMT member, the geoprofessional will be responsible for identification and assessment of risks related to GS activities and development of proper response to them. He /she will maintain a steady line of communication with the PM and PRMT to document and report all risk related actions.

Depending on size and complexity, a project may need a written Risk Management Plan that outlines the roles and responsibilities of the participants as well as the methodology of performing risk management for the project.

## **Risk Identification**

The first step in managing risks is to identify any and all risks that may affect the project outcomes. As stated before and due to several factors, geotechnical investigation is prone to a variety of risks. The risks may be technical, external, environmental or organizational in nature or could be a combination of two or more types. Examples of risks common to most geotechnical explorations are risks associated with discovering subsurface contaminants despite initial hazardous waste clearance, delayed resource and regulatory agency drilling permits or right of entry agreements, striking underground or overhead utility lines, etc. However, each geotechnical investigation is unique and there may be project specific risks that must be identified by the geoprofessional in the early stages of the project.

There are several techniques that could be used for risk identification. Brainstorming, checklist analysis using historical information and interviewing experts are among the most common tools and techniques for this purpose. Brainstorming sessions may be held internally within GS or at the PRMT level for the overall project risks. In the former case, the geoprofessional in charge of the project utilizes the knowledge and experience of other GS staff in similar projects to identify all potential risks associated with geotechnical investigation and design. The latter are usually conducted by the Project Manager or Risk Manager with participation of all PRMT members including the geoprofessional where he /she could share the geotechnical related potential risks with the team.

In addition to identifying the potential risks, the geoprofessional should identify the impact of each risk on project objectives (cost, schedule, scope, quality) if it occurs and outline the assumptions used in this risk assessment. It may also be necessary to identify the potential response to a risk although this task falls under “Risk Response Planning” to be discussed later in this section.

The output of the risk identification process is a Risk Register. The risk register documents the identified risks and other information associated with them as described above. Developing a risk register is the joint responsibility of PM, project sponsor and the project team. This living document will be maintained and updated throughout the project life cycle and will serve as a reference to PDT members to monitor the status of the risks. GS staff are advised to utilize the risk register template available at <http://onramp/riskmanagement> to identify and document geotechnical related risks. Since project managers may solicit the individual risk registers from functional units to compile and develop the overall project risk register, this will highly facilitate the process.

Once the geoprofessional identifies a risk and records it in the risk register, he / she will be the designated “risk owner” and will be responsible until the risk is mitigated or retired.

## Risk Analysis

Once project risks have been identified and recorded in the risk register, the geoprofessional must address two major questions:

- 1) What is the probability or likelihood of the risk occurrence?
- 2) If the risk occurs, what would be its impact on project objectives, mainly cost and schedule?

Risk analysis is a process that aims at responding to these questions. There are two general methods of risk analysis, namely qualitative and quantitative risk analysis. While the main purpose of the former is prioritizing risks for further assessment, the latter quantifies the impact of the identified risks on project objectives. The [“Project Risk Management Handbook: A Scalable Approach”](#) requires qualitative risk analysis for level 1 and 2 projects while mandates quantitative risk analysis for level 3 projects.

In performing qualitative risk analysis for level 1 projects, the geoprofessional makes a judgment on the likelihood of the risks identified during the previous process and verifies their priority as either high, medium or low. This risk rating will be recorded in the risk register and will guide the PRMT to address the risks based on their priority. It will further assist the team with the level of effort that must be spent to address each risk.

Since level 2 projects have a higher estimated capital and support cost, they require a more definitive rating of risks in terms of probability of occurring and degree of impact on project objectives. The geoprofessional may exercise expert judgment to assess the likelihood of technical risks and their impact on projects. Evaluation of risks of external and environmental nature, however, requires further collaboration and consultation with other functional representatives and maybe conducted with the help of other PRMT members. In order to assist with the definition of probability and rating, the [“Project Risk Management Handbook: A Scalable Approach”](#) has established a table which designates a rating for each probability range as well as the corresponding impact. Numerical values that are assigned to each rating (probability number and impact number) will then be presented on a Probability – Impact Matrix. This matrix can be used for each identified risk to derive a single numerical value (impact score) for a certain project objective. Utilizing this matrix, one could obtain cost scores and /or time scores as a function of the probability number and impact number. Higher impact scores signify the priority of a risk and the required response.

With increasing cost and /or complexity of a project, a qualitative risk analysis may not sufficiently address the potential effects of identified risks on project objectives. In order to quantify the probability of risks and their impact, a quantitative risk analysis must be performed on level 3 projects. Quantitative risk analysis generates probability distributions that indicate the likelihood of achieving project cost and schedule goals.

Simulation techniques such as a Monte Carlo process have been successfully utilized to build a model of the project cost or schedule and evaluate the effect of uncertainties through successive iterations.

Quantitative risk analysis is usually conducted by a risk management professional using the input provided by the PRMT. The geoprofessional must be prepared to assist with this analysis by providing expert opinion on: 1) the probability of risk occurrence, and 2) three-point estimate scenarios for time or cost elements of the project. Simulation models can subsequently be run using the data provided by the PRMT in the risk register to generate risk probability curves for cost and time. These curves essentially depict the probability of completion of a project at a certain cost or with a certain duration.

### **Risk Response Planning**

Upon identifying and analyzing credible risks, a plan of action for responding to risks must be developed. The geoprofessional is considered the risk owner for all geotechnical related risks previously identified and will be responsible for providing an appropriate response. Response strategies for negative risks (threats) usually fall within one of the following categories:

1. **Avoidance:** This strategy aims at eliminating risks through making changes to project. An example (that will be used throughout this section for the sake of comparison between strategies) is a site that is suspected of being contaminated and poses a risk of encountering hazardous waste materials during subsurface investigation. By changing the alignment to an area with definite hazardous waste clearance, this risk can be avoided.
2. **Transference:** This strategy transfers the risk and liabilities associated with it to a third party. In the example of the potentially contaminated site, a proper risk transfer strategy is utilizing the services of an A&E contractor to perform the subsurface investigation. In this case, should the risk of encountering contaminants occur, the consequences will be transferred to and borne by the contractor.
3. **Mitigation:** The purpose of risk mitigation is taking appropriate measures to either reduce the likelihood of the threat or ease the consequences should it occur. If site contamination is a perceived risk, a mitigation strategy is to work with District Environmental - Hazardous Waste unit to obtain a definitive clearance. Such clearance can only be obtained through conducting field investigation to detect hazardous materials.

4. Acceptance: Accepting a risk indicates a tendency by the PRMT and PM to defer the response to when the risk occurs in lieu of taking measures to address it now. This could be due to relatively low importance of a risk or lack of other acceptable response strategies. In the previous example, by accepting the risk of site contamination, we agree to perform the subsurface investigation and address this risk if /or when it occurs.

It is the responsibility of the PRMT to evaluate viable risk response strategies and select the most appropriate ones. The response is recorded in the risk register and the risk owner (the geoprofessional in case of geotechnical related risks) will be tasked with its implementation.

### **Risk Monitoring and Control**

Throughout the life of a project, several risks receive proper response. However, they may leave behind secondary or residual risks. Some risks may retire and new risks may be identified. New response strategies may also be established to handle existing and new risks. Since risk register is a living document, it must be constantly monitored and updated. Furthermore, there is a need to control the procedures outlined in the risk management plan and evaluate their effectiveness with respect to the previously established criteria. As a member of PRMT, the geoprofessional should participate in all risk monitoring and control activities such as risk assessment sessions and status meetings.

### **PROJECT SCHEDULING AND RESOURCE MANAGEMENT (PRSM)**

PRSM is an acronym for "Project Resourcing and Schedule Management" and is an enterprise project management tool that is intended to provide scheduling and timesheet capabilities for Caltrans Capital Outlay Support (COS) program. PRSM will enable Caltrans to effectively manage State employees' time in its COS program and is used by approximately 10,000 project delivery staff including DES – Geotechnical Services (GS).

Benefits that GS staff will obtain from PRSM include the following:

- Ability to view current cost and schedule information using a web browser
- Ability to view resource availability
- Comparison of project actual costs versus the planned budget
- Integration with Staff Central to ensure accurate time charges
- Estimation of future workload for supervisors
- Creation of project plans based on similar projects

## Resource Management

All GS personnel working on Capital projects and specific WBS tasks are expected to use PRSM. In PRSM, resources will be assigned to tasks by E-FIS units or to a named individual within the unit. In either case, the commitment of completing a specific task at a certain allocated resource will be made by the supervisor of the unit.

GS supervisors known as Unit Owners in E-FIS will work with Project Managers (PM's) and Task Managers (TM's) in PRSM as Resource Managers (RM's) to get the appropriate resources assigned to specific tasks and time frames in projects. GS Office Chiefs can delegate the RM roles to their Branch Chiefs to manage resources more effectively.

The following is a summary of the major highlights of resource management in PRSM:

- RM's are responsible to ensure their E-FIS unit and/or specific personnel are assigned to active projects or they will not be able to charge to the project.
- RM's submit proposals to the TM if it is necessary to change an existing resource allocation or time period.
- RM's monitor resource utilizations and balancing.
- Charges can no longer be made to WBS levels other than what they have been planned in PRSM.

## Task Management

PRSM will facilitate full implementation of DES task management. Consequently, the role of TM will be standardized statewide to support the vision specified in [Deputy Directive 93 – Task Management](#) and also in the [“DES Task Management Roles and Responsibilities”](#).

The following is a summary of the major highlights of GS Task Management in PRSM:

- Geotechnical Design Branch Chiefs are TM's for WBS 240.65, 240.70, and 240.80.
- PRSM requires that every task in a workplan have an assigned TM.
- TM's are responsible for cross-matrix management of the scope, schedule and budget of their deliverables.
- TM's are also responsible for monitoring the scope, schedule and budget of all of their subordinate lower-level tasks.

- TM's will create and review task and resource proposals (requests to change the project schedule or budget).
- TM's determine tasks that need to be marked "Open" or "Closed" for Time Entry.
- TM's specify alternates who can act on their behalf.
- TM's update percent complete for their tasks (WBS 240.65, 240.70, and 240.80).
- TM's monitor cost and schedule performance indexes for their tasks and take corrective action when necessary.
- TM's review resource proposals to change "Estimate to Complete" (ETC) or dates and determine the appropriate action.

### Time Charging

PRSM will be integrated with Staff Central to improve charging practices by pre-populating employees' timesheets with the correct charging information. Only individuals or units that are resourced on a workplan will be able to charge time in the time period that has been specified.

GS TM's are responsible for opening and closing geotechnical tasks for timekeeping. Personnel can no longer charge their time to a task after the it has been closed.

Further information regarding PRSM and its implementation can be obtained from the following sources:

HQ PRSM information (<http://onramp.dot.ca.gov/hq/projmgmt/index.jsp?pg=16>)

PRSM Frequently Asked Questions (FAQs)  
(<http://onramp.dot.ca.gov/hq/projmgmt/index.jsp?pg=35>)

DES Roles and Responsibilities for PRSM Implementation  
([http://onramp.dot.ca.gov/hq/des/docs/DES\\_PRSM\\_R&R.pdf](http://onramp.dot.ca.gov/hq/des/docs/DES_PRSM_R&R.pdf))